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AN APPRAISAL OF SOME FOREST INSECT CONTROL PROJECT RESULTS

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BERKELEY, CALIFORNIA
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BY

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Since 1931 forest insect activity in the ponderosa pine and mixed conifer types of California and in the east as well as the west side stands, has been great. The peak of infestation was reached in most areas during 1931 or 1932 and, as a consequence considerable activity in controlling the epidemic infestations was exhibited by both the Forest Service and the National Park Service. The severity of the infestations attracted the attention of private lumber companies but, with the exception of a relatively few organizations, no active participation in the control of forest insects resulted.

The establishment of study plots by the Bureau of Entomology as a part of the Regional Survey project furnished some opportunity to evaluate the effectiveness of control measures under the climatic and infestation conditions existing during that period. These plots, which have been cruised annually in order to determine the extent and type of insect loss occurring in the virgin stands, furnished a sample of the conditions on the treated as well as on untreated areas. In addition to the projects of 1931 and 1932 it has been possible, due to the long series of records secured from plots in the Happy Camp-Lava Beds area of the Modoc National Forest, to evaluate the results of the 1928-1929 control project conducted by the Pickering Lumber Company.

A total of ten control project results are possible of some analysis by the plot method. These include all the major projects of 1931 and 1932 as well as a few smaller projects. The total acreage covered by the treatments, which were in the Modoc, Shasta and Sierra National Forests and the Yosemite National Park, is 164,580 acres. On this area, 18,382 trees and 32,523,030 b.m. were treated at a cost of $98,806.35. These figures represent only winter brood losses on the areas and the cost of treating those partial seasonal losses.

It is possible to consider only the value of the timber saved by a control project in determining the value of the project. It is impossible to compute the indirect values derived from hazard reduction through the felling of potential snags or from other sources.

The timber saved through the treating process is not removed from further hazard, but is liable year after year to be attacked by insects. Where conditions for growth of timber remain critical the stand is subjected to great hazard, but where growth is fairly fast the danger, except during epidemic cycles of infestation is considered to be much less. If the effects of a control project last more than one year, as apparently is the case, the control project accumulates value.

In computing the effect of control, the losses on treated and untreated plots have been used as a basis. It is admitted that any one plot, compared to another, may not give even an approximate picture of conditions. Much depends on the selection and the judgment of the one making the selection. Attempt has been made in this study to select plots in the near vicinity of the project areas and to use the results from only those in the same timber type and judged to be following the same infestation trends. However, even within a control project area it often has been noticed that

the infestation in different parts of the area is different. Such local differences must be taken into account in comparing the results.

In some cases there are no plot results available for comparison with the treated plot figures. In such cases little attempt has been made to apply outside figures for untreated areas and judgment of the effects of control are largely qualitative.

MODOC PROJECTS

Five control projects on the Modoc National Forest are subject to analysis and they, in addition to the Shasta Control Project, constitute the tests of control in the east side type of forest. Two projects on the Modoc, one on the Lassen and one on the Shasta National Forest, have just been completed. The results of these projects will not be available for at least another two years, because their effects cannot be measured until the losses of at least two more seasons are known. For the same reason the results of the 1932 projects are not entirely complete.

1928-1929 Badger Control Project

Acreage.....17,360
Trees treated.....3,288
Volume treated.....2,495,514 b.m.
Cost.....$12,749.45
References.....

Keen, F. P. Western Pine Beetle Survey, Happy Camp-Lava Bed Area, Modoc National Forest. Nov. 1928.

Keen, F. P. Report on Insect Control Work Carried Out by the Pickering Lumber Company on the Badger Sale Area, Modoc National Forest. Aug. 1929

This project was conducted by the Pickering Lumber Company on advice of the Bureau of Entomology in the Badger township (T. 44N, R 8E) and Pickering lands to the south (T 43N). The work was partial control and partial salvage by logging infested trees. The project costs given above were computed as if the complete project was of the usual type of control. Three treated plots and four untreated plots are available for comparison. The results from these plots are as follows:-

TABLE I
1928-1929 Badger Control Project

		1928	1929	1930	1931
Ave. 3 treated plots.	Loss per Acre b.m.	831	101	69	235
	% of 1928 loss.		12.2	8.3	28.3
Ave. 4 untreated plots.	Loss per acre b.m.	747	107	72	205
	% 1928 loss		14.3	9.6	27.4

TABLE I
(Continued)

Theoretical loss without control b.m. per acre	118	80	227
Effects of control b.m. per acre	+17	+11	-8
b.m. " sect.	+10,880	+7,040	-5,120

The above figures and those on the previous page are based on the assumption that, if no control had been done, the treated plots would have reacted as did the untreated plots. There is, apparently, no better method of comparison. On that basis we note that the treated plots have a naturally heavier infestation than the untreated. This has been substantiated by the loss records of other years and by observations. Accordingly, the reduction caused by control extends over a two-year period, losses returning to the higher level in 1931. The net gain resulting from the control is figured as a differential of 2.1% in 1928 and 1.3% in 1930 or a total of 3.4%. This amounts to 28 b.m. per acre or 17,920 b.m. per section. The cost of the project was $.734 per acre and the value of the 28 b.m. of timber saved per acre considering its worth at $3.00 per m.b.m. is $.084. The project thus lost about $.65 per acre. The timber saved was worth but about $1,485 and the net loss on the project was about $11,291.

1931-1932 Badger Control Project

Acreage.....19,680
Trees treated.....1,932
Volume treated.....2,344,950 b.m.
Cost.....$9,478,09
References.....

Woodbury, T. D. and Salman, K. A. Working Plan, Pickering Sale Control Project, Badger Unit, Modoc Nat'l. Forest. Nov. 1931

Parker, A. L. and Buck, Ernest. Report on Beetle Control Operations. Season of 1931-32. Mar.1932

This project, which covered much of the area treated in 1928-1929 with the addition of some lands to the north and east, was completed through cooperative effort of the Pickering Lumber Company and the U. S. Forest Service. The infestation showed definite tendencies towards increasing, in fact, later investigations have shown that it was the beginning of an epidemic cycle. The plot results applicable to this control project are as follows:- (see TABLE II on the following Page.)

TABLE II

1931-1932 Badger Control Project

		1931	1932	1933 est.
Ave. 4 treated plots.	Loss per acre b.m.	243	229	144
	% 1931 loss		94.2	59.3
Ave. 3 untreated plots.	Loss per acre b.m.	251	392	258
	% 1931 loss		156.2	102.8
Theoretical losses without control b.m. per acre			380	250
Effects of control per acre b.m.			+151	+106
per sec. b.m.			+96,640	+67,840

The same basis of comparison as was used in the 1928-1929 control figures was used in the above table. The untreated plots showed an increase in the loss of 1932 whereas the treated plots showed a decrease. A general decrease, due to the effects of the low temperatures of the winter of 1932-33, was exhibited by both untreated and treated plots in 1933. However, the treated plots still showed a favorable balance when compared with 1931, the year of treating. Losses of 1934 are not yet available for the record so that it cannot be determined if the infestation, without further treatment, has returned to an approximately normal relationship to untreated plots.

This project, judging from all plot records taken in the Modoc National Forest, was against a rapidly increasing infestation. The control project broke the trend of the infestation and resulted in a decrease which, when compared with the conditions in untreated areas, resulted in considerable savings over a period of two years at least. If the above figures can be considered average, it can be estimated that timber to the amount of 5,057,760 b.m., and at $3.00 per m.b.m. having a value of about $5,173 was saved by the project. The net saving over and above costs was about $5,700.

1932-1933 Badger Control Project

Acreage.....8,920
Trees treated.....1.215
Volume treated.....1,062,310
Cost.....$6,436.24
References.....

Salman, K. A. Conditions and Insect Control Recommendations, Badger Unit, Season of 1932. October 1932.

Parker, A. L. and Buck, Ernest. Report on the Badger Springs Insect Control Project, Season 1932-33. Jan. 1933.

This project covered but a part of the area it was originally intended to treat due to the killing of about 65% of the brood in December of 1932 and abandonment of the project. None of the area treated in 1931 was included in the treated area of the 1932 project. The project appeared to be directed against an increasing infestation although there is some question as to whether the epidemic cycle had reached its peak in that year. The effects of the low temperatures disturbed the natural tendencies throughout the treated as well as untreated areas. Due to the fact that sufficient time has not elapsed in which to secure enough records and the fact that all nearby and comparable plots that might serve as checks of the treatment were under the influence of previous control treatments, complete comparison is not possible. However, the plot results in the treated area, basing the 1933 loss on estimates made with regard to the abnormal correction factor indicated necessary by the 1933-34 control project results are as follows:-

TABLE III
1932-33 Badger Control Project

	1932	1933 est.
Ave. 2 Loss per treated acre b.m.	303	122
plots. % 1932 loss		40.3
Ave. 3 Loss per untreated acre b.m.	176	100
plots. % 1932 loss		56.8
Theoretical loss without control b.m. per acre		172
Effects of control b.m. per acre		+50
b.m. per sec.		+32,000

It is realized that the three plots used to check the results of the treated plots were controlled in 1931 and, accordingly, were affected during 1932 and 1933 by the 1931 project. However, the reduction of brood secured on those plots in the 1933 season is rather close to the average reduction found to have occurred when all plots are taken into consideration and thus is probably nearly normal. If 56.8% represents less than normal residue in untreated timber, which is probably the case, the amount of timber saved in 1933 due to the 1932 project would be greater than is indicated by the figures. The project cost about $.72 per acre and the savings of 50 b.m. per acre amount to $.15. The net loss on the project is computed to be about $.57 per acre or about $5,084 on the project. However, there are several factors to be considered in judging the worth of this project. The costs are extremely high due to the fact that the camp was shut down soon after getting under way. In addition, the reduction of brood through the action of low temperatures affected the treated as well as the untreated areas. There is no means of estimating how profitable the operation would have been had the infestation continued the epidemic cycle that appeared to be in progress, or if no low temperatures had occurred.

OTHER CONTROL PROJECTS

Due to the fact that all other control projects are either more recent, or that sufficient information on untreated plots has not been secured, conclusions that can be drawn from other projects at this time are largely qualitative in nature.

MODOC NATIONAL FOREST

1931-32 White Horse Control Project

Acreage.....12,140
Trees treated.....1,027
Volume treated.....1,454,280
Costs.....$3,242.83
Reference.....
Parker, A. L. and Van Dewalker, C. A.
White Horse Insect Control Project,
Spring 1932, May 1932.

This project was a cooperative undertaking of the McCloud River Lumber Company and the U. S. Forest Service. It was directed against a rising infestation following the same trends as that in the Happy Camp-Lava Beds area to the northeast. Results from plots are as follows:-

TABLE IV

	1931	1932	1933
Treated plot			
b.m. per acre	192	111	144
% 1931 loss		57.8	75.0
Untreated plot			
b.m. per acre	213	487	147
% 1931 loss		228.6	69.0
Theoretical loss without control			
b.m. per acre		439	132
Savings from control			
b.m. per acre		+328	-12
b.m. per sec.		+209,920	-7,680

It is not believed, in this case, that the check plot reflects the same trends as occurred in the treated area. However, the net savings in the two years following control, based on the check plot results would be 328 b.m. per acre giving a gross saving of about $11,950 worth of timber on the project or a net profit of about $8,700. Although qualitative observations indicate that a considerable amount of timber was saved in 1932 through the control, it is not believed that the value of that timber was as great as indicated by the above figures.

1932-33 Buck Creek Control Project

Acreage.....1,840
Trees treated.....196
Volume treated.....293,950
Cost.....$1,070.30
Reference.....
Bacon, R. S. Insect Control Project
Buck Creek Unit, 1933. May, 1933

This project was conducted by the U. S. Forest Service after the low temperatures of the 1932 winter had resulted in an estimated mortality of about 45% of the brood. Analysis of trees during the control project showed considerably more natural mortality. The plot results, taken from the one plot in this area and not comparable with any check plot results, are as follows:-

TABLE V

	1932	1933 est.
Loss per acre, b.m.	455	58
% of 1932 loss	[illegible]	12.7

It is certain that the type of infestation as well as the infestation cycle is not the same in this area as in the Badger Unit of the Modoc Forest. Accordingly, it may be that some of the decrease has been due to natural reduction of infestation intensity. However, it also seems as if the combination of natural and artificial control factors was more effective than the former alone.

SHASTA NATIONAL FOREST

1932-33 Cayton-Soldier Mountain Control Project

Acreage.....3,950
Trees treated.....,.925
Volume treated.....692,680 b.m.
Cost.....$2,845.00
Reference.....
Van Dewalker, C. A. Report of Seasonal Work, 1933, May, 1933.

No satisfactory check of this control project is possible due to the fact that type and climatic differences are so great that it is impossible to secure comparable untreated checks. In addition, lack of definite information concerning the extent of error of the standard correction factor for seasonal losses is not available. However, some indication of the trends is possible by using the nine plots cruised in the southeastern portion of the Shasta National Forest, only two of which were untreated in 1932-33. The quantitative results, however, cannot be considered entirely descriptive of the situation.

TABLE VI

	1932	1933 est.
McCloud Control, Site II		
Ave. 2 treated plots.		
b.m. per acre	164	95
% 1932 loss		57.9
U.S.F.S. Control, Site III-IV		
Ave. 5 treated plots.		
b.m. per acre	248	133
% 1932 loss		53.7
Untreated Site III		
Ave. 2 plots		
b.m. per acre	164	60
% 1932 loss		36.5%
Theoretical loss without control		
McCloud Control, b.m. per acre		60
U.S.F.S. Control, b.m. per acre		91
Effects of control, savings per acre b.m.		
McCloud Control		-35
U.S.F.S. Control		-44

The above table appears to show that the control was about equally effective in reducing the infestation on Site II and Site IV areas. However, the untreated check plots show a greater reduction than was shown on the treated areas. As stated above, it is not felt that this relation was actual although it may indicate, in agreement with qualitative observations, that the control in the better type timber could have been dispensed with and that the control in the poorer site areas, where the stands are growing under extremely critical conditions, was not markedly effective.

YOSEMITE NATIONAL PARK

1932-33 Yosemite Control Project

Acreage.....48,909
Trees treated.....3,598
Volume treated.....11,468,960 b.m.
Cost.....$28,337.50
Reference.....
Ernst, Emil. Report on Insect Control, Spring 1933. July, 1933.

This control project, which covered a large acreage of ponderosa pine and mixed conifer stands along the west boundary of the Yosemite National Park and extending from the Wawona basin on the south to the Ackerson Meadow area on the north, was directed against what was believed to be a declining infestation of the western pine beetle in ponderosa pine and an epi-

demic infestation of the mountain pine beetle in sugar pine. Although the project was initiated as a control of the western pine beetle, the great loss in both trees and volume caused by the mountain pine beetle made that the more important phase of the project. The plot, which is representative only of the mixed conifer stands having a heavy sugar pine volume in the Ackerson Meadow area, has been cruised since 1931. The results of this plot are as follows:-

TABLE VII

	1932	1933 est.
Treated plot loss		
b.m. per acre, all species	773	576
ponderosa pine	266	233
sugar pine	507	343
% 1932 loss, all species		74.5
ponderosa pine		87.6
sugar pine		67.6

This plot is considered to be Site II quality. The tremendous volume losses, which resulted from an infestation of but 92 trees in 1932 and 47 trees in 1933 indicates the extent of the drain on the stand. It cannot be considered, at the present time, that these losses represent an epidemic infestation. However, they do represent more drain than the virgin overmature stand can bear without a net loss.

The only opportunity to check these results with an untreated area is afforded by the ECW cruises reported by Patterson (1). These data, however, are estimated total losses based on observation and strip cruises. plot. Much of the timber concerned in the units is not of the same site or type.as the/ Results are as follows:-

TABLE VIII

	1932	1933 est.	% 1932 loss
Big Creek -- all species	400	640	160.0
b.m. per acre ponderosa pine	63	388	615.8
sugar pine	337	252	74.8
Moss Creek			
b.m. per acre all species	49	53	108.0
ponderosa pine	38	48	126.3
Sugar pine	11	5	41.7
Berkeley Camp			
b.m. per acre all species	872	372	42.7
ponderosa pine	426	173	40.6
sugar pine	446	199	44.6

1. Patterson, J. E. Report on ECW Surveys and Control Work Carried Out During the Past Season on the Stanislaus National Forest, February 1934.

TABLE VIII
(Continued)

Diamond "O"				
b.m. per acre	all species	613	434	70.8
	ponderosa pine	399	258	64.7
	sugar pine	214	176	82.2
Average all areas				
b.m. per acre		421	288	
% 1932 loss			68.4	

As would be expected, this record shows considerable variation and appears impossible of analysis in comparison with the plot results. However, the general decrease, without control, appears to be similar to that secured on the control project. The fact that the plot was on the western boundary of the control project undoubtedly accounts for the similarity. In all except the Big Creek area, the sugar pine losses appear to show decreases but the ponderosa pine losses do not show the same uniformity.

SIERRA NATIONAL FOREST

Three projects are subject to plot analysis on this forest. These are the Sugar Pine Sale of 1931-32 and of 1932-33 and the Fence Meadow Project of 1932-33. The figures concerning these projects are as follows:-

1931-32 Sugar Pine Sale Project.

Acreage.....19,310
Trees treated.....2,733
Volume treated.....4,094,000 b.m.
Costs.....$14,605.00
Reference.....
Gustafson, C. A. Sugar Pine Sale Project, Insect Control Report, Sierra National Forest, Chiquito, Rock Creek and Cascadel Areas. July 1932.

1932-33 Sugar Pine Sale Project

Acreage.....11,092
Trees Treated.....1,438
Volume treated.....4,563,000 b.m.
Costs.....$9,778.00
Reference.....
Gustafson, C. A. Insect Control Report, Sierra National Forest. Fence Meadow and Sugar Pine Sale Projects. July, 1933.

1932-33 Fence Meadow Project

Acreage.....21,379
Trees treated.....2,590
Volume Treated.....4,229,000 b.m.
Cost.....$9,018.00
References.....Loc. cit.

Cascadel area.-R.S.7, a Bureau of Entomology plot, lies in this a area. The plot records are as follows:-

TABLE IX

	1931	1932	1933 est.
B.m. per acre	921	398	282
% 1931 loss		43.2	30.6

This plot was controlled in 1931-32 and 1932-33. ECW control on this area has been completed this winter. The marked decrease in the infestation appears to reflect the effectiveness of the insect control work. However, somewhat comparable areas in the vicinity of Bass Lake appear to have shown a somewhat similar natural decrease which, however, amounted to less than 10% in 1932 but appears to be much more in 1933. Qualitative observation of the results would indicate a benefit through control, particularly in the first year and against the peak of the epidemic infestation. The losses of the second year, however, appear to be the equal of uncontrolled areas so that the chief saving of timber resulted from the first project. The 1931 project was directed against an infestation not quite at its peak whereas the 1932 project was against a decreasing infestation. These results are in line with other control projects in which control of heavy epidemic infestations, that were increasing, was more productive of savings.

Chiquito area. Two plots in this area were subjected to control in 1931 but not in 1932 or this year. The plot results follow:-

TABLE X

	1931	1932	1933 est.
Placer Plot (low elev.)			
Site III			
b.m. per acre	216	174	108
% 1931 loss		80.6	50.0
Jackass Plot (high elev.)			
Site II			
b.m. per acre	241	269	332
% 1931 loss		111.6	137.8

The Chiquito basin apparently has not followed the general trends of infestation that were found to occur in the more marginal areas to the west in Rock Creek, Saginaw and Cascadel basins. However, the infestation in timber at the lower elevations did suffer from a mild fluctuation in sympathy with but not nearly to the intensity of the infestations in the above named areas. Timber at the higher elevations, which is largely of Site II

quality and contains a large amount of sugar pine apparently is following its own infestation trend. The probable reason for this lies in the difference of the trends of western pine beetle and mountain pine beetle infestation.

Control effects are not evident in the better site of the basin. However, the plot is on the northeastern boundary of the project area and thus its record may have been influenced from outside sources. The record of the Placer plot does not appear to show marked effects of control.

Fence Meadow Area. This area, which was treated in a 1932-33 project is sampled by one plot. The timber is Site II and contains a high percentage of sugar pine. Results on the plot are as follows:-

TABLE XI

	1932	1933 estimated
B.m. per acre		
all species	2049	671
ponderosa pine	1340	278
sugar pine	709	393
% 1932 loss		
all species		32.7
ponderosa pine		20.7
sugar pine		55.4

Considerable reduction in losses was secured following the control project in this high quality timber. However, the sugar pine losses did not decrease as greatly as the ponderosa pine losses. It is believed that this may have been due to the fact that the ponderosa pine infestation cycle reached its peak in 1932 in this area and was somewhat ahead of the cycle of infestation in sugar pine.

There are no adequate checks of any of the Sierra control projects. This is due, for the most part, to the topography of the country which gives each basin conditions of environment and climate that may vary considerably from adjoining and similar basins. The only untreated plot in the Sierra Forest is that in Blue Canyon known as R.S.13. The figures on this plot are as follows:-

TABLE XII

	1932	1933 est.
B.m. per acre		
all species	695	198
ponderosa pine	618	132
sugar pine	77	66
% 1932 losses		
all species		28.5
ponderosa pine		21.4
sugar pine		85.7

If we can consider these plot results available for comparison with those in Fence Meadow, it is apparent that the control gave little

benefit in the ponderosa pine infestation but resulted in about a 30% differential in favor of treatment of sugar pine. However, as stated before, it is not certain that the comparison is fair.

DISCUSSION OF CONTROL PROJECT RESULTS

Badger Projects

There has been so much activity in the control of forest insects in the Badger Unit of the Modoc National Forest that there is opportunity to make an accounting of the value of forest insect control under the climatic and other environmental conditions to be found in the area as well as to ascertain the value of entomological boundaries and the effects of several years of insect control work in one area. The basic data for this discussion lies in the following table.

XIIII

INSECT CAUSED LOSSES -- BADGER PLOTS

	1928		1929		1930		1931		1932		1933 est.	
Plot #	B.m. per acre	% prev. year	B.m. per acre	% prev. year	B.m. per acre	% prev. year	B.m. per acre	% prev. year	B.m. per acre	% prev. year	B.m. per acre	% prev. year
1	293		118	40.3	143	121.2	372	260.1	375°	100.8	183	48.8
2	1051		174	16.6	48	27.6	214	445.8	440°	205.6	311	70.7
3	787		122	15.5	74	60.7	166	224.3	362°	218.1	281	77.6
4	1008*		106	10.5	37	34.9	276*	745.9	389°	140.9	276	71.0
5	931*		113	12.1	72	63.7	257*	356.9	209°	81.3	119	56.9
6	594		50	8.4	66	132.0	267*	404.5	163°	61.0	116	71.2
7	555*		83	14.9	99	119.3	173*	174.7	156°	90.2	63	40.4
8			256		80	31.3	196	245.0	348*	177.0	106	30.4
9					55		242*	440.0	355*	106.6	138	53.5

* -- year of control operation ° -- year of freeze mortality

Project boundaries. Where Bureau of Entomology recommendations have been considered in control projects, an attempt has been made to secure satisfactory entomological boundaries. In some cases, however, imperfect boundaries have had to be used. The data at hand furnishes information on the value of satisfactory boundaries.

In the 1928-29 control project plot 4 lay on the western boundary of the treated area. Directly west of it was plot 2 and east of it lay plot 5, one mile distant from the control boundary. The percent reduction secured in the infestation of 1929 was 89.5% on plot 4, 84.5% on plot 3, and 87.1% on plot 5. It would appear that the plot next the boundary secured the greatest benefits of control. However, the differences are so small that, except for the fact that the treated plots show a slightly greater reduction than occurred on the untreated plot, there is no marked or definite difference in the trends of the infestation on the three plots. No reinfestation of the treated

plot next the boundary is noticeable and it is felt that this may be due to the fact that the infestation was decreasing naturally and rapidly.

In the 1931-32 control project the same plots were treated, or left untreated. Plot 4 suffered a 40.9% increase in the infestation. Plot 3 increased 118.1% and Plot 5 showed a 39.0% decrease. The chief points of difference between these plots in 1928 and 1931 was in the amount of infestation and in the fact that the infestation was increasing rapidly. The difference in the plots are definite and tend to show that reinfestation, if a proper boundary is not secured, may offset the effects of control work.

The average relation of 1932 infestation to 1931 infestation on the five plots treated in the 1931-32 control project was 96.0%. Plot 7, which was just within the southern boundary of the control project received a slightly better than average benefit from control by decreasing 9.8%. However, the infestation outside the control project and to the south was not of an extremely epidemic nature. Plot 7, on the northern boundary of the control project, received a 49.0% benefit. The infestation to the northwest of this plot, which was untreated, was negligible for at least a mile. That to the north and east was heavy. The infestation to the west and south was treated. Plot 9 was situated about three quarters of a mile southwest of the nearest untreated lands. This plot suffered a 6.6% increase. However, the untreated infestation outside the project area suffered a 77.0% increase.

These results seem to indicate that entomological boundaries, consisting of type or infestation boundaries or major topographical barriers, are of value in increasing or epidemic infestations but of little value in rapidly decreasing infestations. When the percent of reinfestation is considered it also would appear that the amount of infestation directly outside the project boundary in epidemic infestations may be nearly proportional to the amount of reinfestation. Also, in the Badger area it is apparent that the position of the project boundary in relation to open areas may be important. Plots 4 and 5 are within the timber but more or less exposed to the sweep of prevailing winds from the southwest. Plot 6 is near the fringe and exposed to the sweep of wind although bounded on the north and east by heavy untreated infestation. Plot 9 also was bounded on the north and east by heavy infestation but was well within the main timber body and not as exposed to the wind. Plot 7 was also within the main body of timber, was not exposed to the sweep of the wind and, in addition, was bordered by a light infestation.

Effects of insect control and of low temperatures

Three records are available on plots in which no insect control work has been done. In these records (Plots 1,2, and 3) the reduction of the 1933 infestation was 51.2, 29.3 and 22.4% respectively. This reduction may be considered the result of mortality due to low temperatures or a natural decrease or both. However, it is probable that the low temperature effects were greater than the figures indicate for no natural decrease appears probable in view of the proven vigor of the brood before the time of the

freeze. Brood conditions of the fall of 1932, indicated a marked increase in losses was in store, rather than a decrease.

Four plots were controlled in 1931 and had the infestation further reduced by the freeze in 1932. In these plots (Nos. 4,5,6, and 7) the reduction secured in the 1932 infestation was in marked contrast to the increase in the uncontrolled plots. The reduction in the 1933 infestation, which was 29.0, 43.2, 28.8 and 59.6% respectively does not differ enough from that in the uncontrolled plots to warrant definite conclusions. The average reduction in the treated plots was about 6% greater than in the untreated plots.

One Plot (#8) was untreated previous to 1932 but was treated in 1932. Another plot (#9) was treated in 1931 and 1932. In both these plots marked benefits were shown by the 1933 infestation. The reduction in plot 8 was 69.6% and that in plot 9 was 46.5%. It would appear that the treatment of 1932 plus the effects of the freeze was more efficient than the treatment for two years plus freeze effects. However, it must be noted that considerable reinfestation of plot 9 occurred in 1932 subsequent to the control of 1931 and it may be that a similar reinfestation occurred in 1933 due to the fact that the plot was on the southwest boundary of the control area. However, at the time the decision was made to abandon control a freeze mortality of 65% appeared to be as much as would be secured through control and the treatment of a large amount of dead brood seemed a waste of money.

Value of control

Table XIII shows that the minimum loss on any plot during the six year period amounts to a cash loss of about $.11 per acre. The maximum loss amounted to $3.02 per acre. The savings from control against naturally decreasing infestations, although visible for two years after the year of control, do not appear to cover the costs of operation. The savings from control against an increasing epidemic infestation, particularly if control is done at the start of the epidemic cycle, appears to last at least two years and to result in a profit above costs. However, even the minimum loss in the controlled area following control amounts to about $70,00 per section, a loss that is not entirely compensated by increment growth. In fact, a net loss averaging much greater than the minimum gross loss figure appears to be the rule. Under these conditions, the advisibility of trying to reduce the losses by means of the method of attempting to destroy as much of the brood as is possible, can be questioned.

During the six year period and excluding the Pickering control project of 1929-30, of which no information is at hand, a total of $28,663.78 has been spent in protecting the timber on approximately 30,200 acres. This cost reaches an average of $.95 per acre for the six years or about $.16 per acre per year. In spite of this expenditure, however, the gross loss, uncorrected for increment, amounts to $3.87 per acre for the six year period, or an average of about $.64 per acre per year.

It must not be understood that these results are an indictment of

of all forest insect control activities. On the contrary they definitely substantiate most of the points brought out by Craighead, et al (2). Their first and second conclusions (P. 1006) are substantiated entirely with the addition that, against decreasing infestations, the amount of timber saved possibly will not be worth the cost. Their other conclusions also appear to be substantiated.

Another conclusion can be drawn from this analysis of Badger Projects. It appears that control work alone, when directed against infestations in stands growing under critical environmental conditions and over a period of years, will save a considerable amount of timber. However, costs and savings will not balance as long as the average amount of timber lost per acre per year under control is of greater value than the cost of control subtracted from the average value of untreated and apparently normal loss. In the case of the 30,200 acre Modoc area the average loss on treated areas would have to be about 33 b.m. per acre per year less than the average untreated loss to pay expenses.

Experimental control in the Devil's Garden area of the Modoc National Forest has shown that volume losses cannot be reduced markedly below the normal for the area by means of insect control projects. This means that we may, through control projects, bring abnormal infestations closer to the normal condition. In the Badger Unit, however, normal losses are much greater than replacement by growth. Control then can only reduce the rate of excessive loss somewhat but cannot reduce losses to a point where increment and losses balance. In spite of control then, we can postulate a more or less continuous net loss with or without control, under the conditions now existing in the Badger Unit of the Modoc National Forest.

OTHER CONTROL PROJECTS

Unfortunately, the data with which to check the effects of control are neither as satisfactory or abundant in other control areas as in the case of the series of Badger Projects.

The Buck Creek Project, which has no check, gives much better results of control plus freeze than were found in the Badger area. The only conclusion to be drawn from this is that a mistake was made in not completing the Badger Project regardless of amount of freeze. In fact, it appears probable that more satisfactory results could have been secured by widespread control projects in the area subjected to the freezing temperatures than are normally secured.

The Cayton-Soldier Mountain Project does not seem to check with this conclusion. However, the areas controlled were partially west side type and partially marginal east side type with infestation cycles follow-

2. Craighead, F. C. et. al. Control Work Against Bark Beetles in Western Forests and an Appraisal of its Results. Journ. For. 39:1001-1018, 1931.

ing neither type closely. Control in this case does not seem to have been effective and there may be undiscovered factors responsible for that lack of effectiveness.

In the Yosemite Project and similar projects in the Sierra Forest, the effects of control possibly are noticeable in some areas.

In the pure ponderosa pine type control near the peak of infestation resulted in a considerable savings for the first year although the losses on the same areas assumed an approximately normal status the second year. Control in the 1932 season against the decreasing infestations did not appear to pay.

In the better type timber, the ponderosa pine portion of the stands appears to have benefitted but slightly through control. It is possible, however, as has been noted in the Fence Meadow Project, that the infestation cycle in ponderosa pine growing on the better sites lagged behind that at the lower altitudes so that normal increase may have been considerable. In sugar pine it is difficult to discern any appreciable benefit from control. The difficulty of determining just what the effects of control have been without available and satisfactory check plots results makes it impossible to draw definite conclusions except that, with control, the losses remain exceedingly heavy in many areas.

CONCLUSIONS AND RECOMMENDATIONS

Control appears to have been unprofitable except under certain specific conditions. However, control cannot be condemned entirely from the data at hand. It is certain that more study must be made of control projects and their effects before it can be concluded the benefits are not worth the cost.

Lines of endeavor in improving control or approving its use should be as follows:-

1. Careful setups to check the results of control projects.
2. Careful appraisal of conditions of infestation preceding and following control.
3. More careful supervision of the entomological phases of control projects including,
   a. Better quality spotting.
   b. More detailed checking of spotting and treating.
   c. Tree analyses on control projects to determine composition.
4. Study on
   a. Methods of reducing costs under present methods.
   b. New and cheaper methods of control.
5. Study of what to do with areas in which the normal loss is resulting in net losses year after year.

6. Determination of the characteristics of epidemic cycles particularly characteristics of years preceeding the cycles or during the early stages.

Cruising of point 1 can be done by utilizing Regional Survey crews and plots. Points 2, 5, and 6 properly belong in the Regional Survey Project. Points 3 and 4, and to some extent other phases of the problem, introduce new types of work.